

# **LIGHTWEIGHT ARMOR AGAINST FIREARM PROJECTILES**

## **FIELD OF THE INVENTION**

The present invention is in the field of armor against regular and armor piercing firearm projectiles and their fragments as well as debris of various objects (collectively referred to herein the specification and claims as *projectiles*), and aims at providing an armor suitable for a variety of purposes such as for making protective garments, for fitting enclosures with armored wall portions and the like.

## **BACKGROUND OF THE INVENTION**

There is a widespread need for protected enclosures with firearm projectile resistant wall portions, transparent or not. Typical examples where transparent such armor is required are shop windows in riot prone areas, armored car windows, fighter plane domes, helicopter windows, domes for a tank commander post, etc.

According to the prior art it is customary to use for such purposes laminated glass panels, e.g. 11 to 40 mm thick or even more, which by the effect of their mechanical properties are resistant against the penetration of various types of firearms. Where it is required to increase the penetration resistance of the armor, the thickness has to be increased, thereby reducing the visibility of such armor panels. Furthermore, such panels are very heavy, weighing about 3 to 4 times more than an opaque armor, and also costly and therefore impractical for many purposes. There is thus an ever increasing need for armor material, in particular lightweight and transparent armor shields.

There is also a widespread need for firearm projectile resistant pliable material, e.g. for making protective garments, bullet resistant tarpaulins and the like. There is furthermore a need for lightweight opaque armor against firearms.

Whilst prior art armor shields are aimed at providing an armor which deforms the shape of the projectile or of its fragments, thus decreasing its penetration ability by reducing its kinetic energy, it is an object of the present invention to provide an armor which diverts the trajectory of the projectile or the fragments thereof. This object is carried out whilst carrying out the above needs.

GOVERNMENT PROPERTY

#### **GENERAL DESCRIPTION OF THE INVENTION**

It is the general object of the present invention to provide an armor which diverts the trajectory of the projectile striking said armor. This object is achieved by imparting the projectile with side momentum as it penetrates through the armor, whereby the trajectory of the projectile is diverted from its original course.

The invention is based on the surprising observation that an armor made of at least one panel of brittle, low toughens material, facing the expected path of a firearm projectile and slantingly introduced in the path of a firearm projectile, subjects the projectile to forces which cause it to be diverted from its original trajectory by impact forces acting on the projectile as it penetrates through the armor.

Additional layers of material may be introduced behind the brittle material, thus imparting the armor further resistance and durability and to increase protection of an object extending behind the armor.

The arrangement is such that the projectile is diverted in direction essentially perpendicular to the panel of brittle material, and where the armor comprises one or more layers of ductile material behind the panel of brittle material, the projectile and fragments of the brittle material will not reach the protected object. The one or more ductile layers may adjoin the

panel of brittle material or may extent at a different angle with respect thereto.

According to one specific embodiment of the invention, the armor comprises a front layer made of an essentially brittle material and a rear layer made of ductile material, adjoining the front layer and constituting a backing layer. The rear layer i.e. the backup layer may be made of metal, typically steel or aluminum, or of a polymer e.g. PU (Polyurethane), PVC (polyvinylchloride), where transparency is required.

By one particular embodiment, the front layer is made of a woven or other playable material, whereby the projectile is imparted with asymmetric impact forces.

According to the present invention the armor comprises a plurality of armor elements arranged in a serrated layout, the armor elements being essentially parallel to one another and extending tilted with respect to an expected trajectory of a projectile.

The material of the front and rear layers used in accordance with the present invention may be transparent or opaque. However, it is in many cases advantageous that it is made of a transparent material, whereby one can see through it. Examples of materials suitable for use as the front layer are glass, glass ceramics, Perspex™, Plexi Glass, PMMA (poly methyl methacrylate), ALON, Sapphir, Spinle, various synthetic materials, epoxy resins etc. – all being transparent, brittle materials. It may be monoblock, laminated or composite, e.g. a glass body sheathed between Perspex™ plates. Transparent Perspex™ plates may be covered with scratch-resistant materials e.g. glass or other suitable coatings. In case of a transparent front layer, it is desired that the rear layer is also transparent.

Where out of the two complementary angles formed between the trajectory of the firearm projectile and the surface of said at least one front layer the obtuse angle is the upper one, the impinging firearm projectile is

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DATE 02/02/00

deflected upwards. In contrast, where the obtuse angle is the lower one an impinging firearm projectile is deflected downward.

An opaque front playable material may, for example, be made of a heavy duty cloth material such as of Kevlar™, Spectra™, and various epoxy materials and the like. Such materials may be used as they are or in composite form, e.g. by being soaked with a suitable different polymeric material which hardens upon curing.

If desired, a plurality of slanting front bodies may be formed together into a multi-layer block in which adjacent layers are suitably glued or cemented to each other. In cases of a thick front body the projectile may be deflected without penetration.

In operation an oncoming firearm projectile penetrates the at least one front body and when it emerges therefrom, either intact or broken up, it is deflected from its trajectory, and does not penetrate the protected object. In some cases the projectile will not penetrate through the front body, made of a brittle, low toughness material.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

For better understanding the invention and to see how it may be carried out in practice, some embodiments will now be described, in a non-limiting manner, with reference to the accompanying drawings, in which:

**Fig. 1** is a schematic illustration showing the manner in which the invention operates in case of one single slanted armor layer made of a brittle material;

**Fig. 2** is a schematic enlargement of a portion of the armor panel according to Fig. 2, illustrating forces acting during penetration of a projectile through the armor panel;

**Fig. 3** is an illustration for two successive slanted armor layers, both made of a low fracture toughens material;

**Fig. 4** is a schematic illustration of an embodiment according to the present invention, with the armor being a composite body comprising several layers of material;

**Fig. 5** is a schematic illustration of still another embodiment of the invention; and

**Fig. 6** is a schematic representation of an armor according to the invention illustrating a serrated structure suitable for protecting a large object.

#### **DESCRIPTION OF SPECIFIC EMBODIMENTS**

Turning first to Fig. 1, there is shown schematically an assembly comprising a slanted armor panel 1 extending in front of a body 2 which is to be protected by the armor panel 1. An oncoming firearm projectile 3 is depicted in form of an arrow and as can easily be concluded from the figure, the trajectory of projectile 3 is essentially normal to the body 2, whilst the armor panel 1 extends at a slant with respect to the trajectory of projectile 3.

In the embodiment of Fig. 1 the armor panel 1 is made of an essentially brittle, low toughens material, such as, for example, glass, glass ceramics, Perspex™, Plexi Glass, PMMA (Poly Metal Meta Acrite), ALON, Sapphir, Spinle, various synthetic materials, epoxy resins et. The armor panel 1 may be transparent or opaque, depending on the intended use of the armor assembly. Furthermore, the panel 1 may be monoblock, laminate or composite, e.g. a glass body sheathed between Perspex™ plates. Transparent Perspex™ plates may be covered with scratch-resistant materials e.g. glass or other suitable coatings.

The arrangement in accordance with this embodiment is such that as the projectile penetrates through the armor panel 1 it is imparted side impact which cause it to deflect from its original trajectory and maintain its deflection as it

emerges from the armor panel 1 in direction of arrow 4. It is appreciated that the in some cases the projectile will not even penetrate through the front body.

As can further be seen, of the two angles formed at the intersection of the trajectory of projectile 3 with armor panel 1, the obtuse angle is the upper one. In consequence, once the projectile 3 has penetrated across panel 1 it is diverted upwards as shown by arrow 4, either as a whole or broken up, and either does not at all hit the body 2, or else is readily intercepted by it without passing across.

An advantage of the armor according to the present invention is that it is essentially lightweight such that it is suitable for use as a personal armor garment, etc. According to some particular embodiments the armor is transparent, rendering it suitable for use as a protection armor for protecting windows and domes of vehicles and crafts, etc.

The arrangement according to this embodiment is such that owing to impact forces the projectile is imparted asymmetric impact forces as it penetrates through the panel, whereby it is diverted from its original trajectory i.e. essentially normal to the plane of the panel, as resembled by the arrow 4.

In Figure 2, which is an enlargement of the portion designated II in Figure 1, there is illustrated a portion 28 of the armor panel designated 18, which gives rise to generating the impact forces acting on the projectile 20, thus imparting it a component force in direction of arrow 30 diverting it in the direction of arrow 26, preventing it from reaching protected body 24, or significantly reducing its kinetic energy.

In the embodiment shown schematically in Fig. 3, in which similar components are marked by similar numerals, there are provided two differently slanted panels 1 and 5. In this arrangement the oncoming firearm projectile 3 is deflected by panel 1 in the manner shown at 6 at which it may still be in a position to penetrate across the second (rear) panel 5 where it is again deflected into the direction shown by arrow 7, the end result being similar as in Fig. 1 but with a larger deflection of the projectile from its original trajectory. The rear layer

may be made of a metal e.g. steel or aluminum, or of a polymer e.g. PU (Polyurethane), PVC (polyvinylchloride), where transparency is required.

In the embodiment of the invention schematically shown in Fig. 4, panel 35 is inclined with respect to the expected trajectory of a projectile, and comprises several layers. A middle layer 36 made of a brittle material and is sheathed by a front layer 38 made for example of a playable material e.g. heavy duty cloth material such as of Kevlar™, Spectra™ and a rear layer 40 of a low toughness material. Layers 38 and 40 are suitable for protecting the panel 36 and preventing shrapnel and debris of the panel 36 from striking object 47. This embodiment operates in a combined way namely, the projectile 42 is imparted asymmetric penetration forces as it penetrates through the layer 36 and then the projectile emerges from layer 40 as indicated by arrow 46, diverted from its original trajectory path preventing it from hitting the protected body 47.

The embodiment shown schematically in Fig. 5 discloses an armor panel generally designated 50 and comprising a front layer 52 and a block 54 composed of a plurality of slanting plates 56 glued or cemented together. A layer of ductile material 58 extends as a backing behind the panel/block 54 and in front of the body to be protected 59. In its passage across block 54 the firearm projectile 60 is diverted by any of the plates 56 which it hits on its way, and it accordingly does not penetrate the rear layer 58.

The schematic illustration of Fig. 6 represents a protective armor generally designated 70 for protecting an object 72. It is readily understood that in order for the armor panel to extend in front of object 72 and inclined with respect to the trajectory of an expected threat 78, it would have to extend as illustrated by the dashed line portion 80 and would consume a significantly large space. Accordingly, the armor consists of a plurality of parallelly extending sections 82, consuming less space.